ERDC/CHL TR-15-10

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Monitoring Completed Navigation Projects (MCNP) Program

Marmet Locks and Dam, Kanawha River, West Virginia

Donald C. Wilson, Larry R. Tolliver, and Kevin L. Pigg

July 2015

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Under MCNP Work Unit Marmet Locks and Dam, Kanawha River, West Virginia

Abstract

Monitoring of the new Marmet Lock, Kanawha River, WV, was performed from 2010 through 2013. The monitoring was conducted because of the many unique aspects of the new lock. The new lock project included a 1,600-feet-long, long-span, thin-walled guide wall in the upper approach and a unique filling and emptying system. The filling and emptying system has a through-the-sill intake, an in-chamber longitudinal culvert system, and Stoney gate valves. The lock was monitored using time-lapse video systems and an underwater remotely operated vehicle. The purpose of this monitoring study was to determine if the project is functioning as designed and as indicated by two physical model studies that were conducted at the U.S. Army Engineer Research and Development Center. The lock culvert system experienced peak average velocities of 18 feet per second, although no adverse pressures were found. A remotely operated vehicle inspection indicated the walls of the culverts were in good condition. The Stoney gate valves are performing well and not showing any signs of unusual wear. The upstream guide wall is not being unduly stressed by tows aligning for entrance into the lock. No significant scour or deposition was found during the annual survey between 2010 and 2013. Vortex and turbulence created during filling and emptying was not adverse. Upstream trash racks beneath the miter gates should be inspected annually. Overall, the new Marmet Lock is performing satisfactorily as designed.

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Preface

The investigation reported herein was conducted as part of the Monitoring Completed Navigation Projects (MCNP) program under work unit Marmet Locks and Dam, Kanawha River, West Virginia. Overall program management of the MCNP is provided by Headquarters, U.S. Army Corps of Engineers (HQUSACE). MCNP is one of the USACE Navigation programs. The U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), is responsible for technical and data management and support for HQUSACE review and technology transfer. The HQUSACE program monitor for the MCNP Program at the time of this study was James E. Walker, Chief, Navigation Branch, HQ. W. Jeff Lillycrop, CHL, was the ERDC Technical Director for Navigation. MCNP program manager during the conduct of this study was Dr. Lyndell Z. Hales, Technical Programs office, CHL.

This research was conducted under general direction of José E. Sánchez, Director of CHL; Dr. Kevin M. Barry, Deputy Director, CHL; Dr. Jackie S. Pettway, Chief of the Navigation Division, CHL; and Dr. Donald L. Ward, acting Chief of the Harbors, Entrances, and Structures Branch (HESB), CHL.

The principal investigator for this study was Donald C. Wilson, HESB. The field data collection effort was led by Terry N. Waller, Field Data Collection and Analysis Branch, CHL. This report was prepared by Donald C. Wilson, Larry R. Tolliver, and Kevin L. Pigg, HESB.

At the time of publication of this report, LTC John T. Tucker III was Acting Commander. Dr. Jeffery P. Holland was Director.

Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
cubic feet per second	0.02831685	cubic meters per second
degrees (angle)	0.01745329	radians
feet	0.3048	meters
feet per second	0.3048	meters per second
inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters

1 Introduction

Monitoring Completed Navigation Projects (MCNP) program

The goal of the MCNP program (formerly the Monitoring Completed Coastal Projects [MCCP] program) is the advancement of coastal and hydraulic engineering technology with respect to USACE requirements. The program is designed to determine how well projects are accomplishing their purposes and how well they are resisting attacks by their physical environment. These determinations, combined with concepts and understanding already available, will lead to the creation of more accurate and economical engineering solutions to coastal and hydraulic problems, thus strengthening and improving design criteria and methodology, improving construction practices and cost effectiveness, and improving operation and maintenance techniques. Additionally, the monitoring program will identify where current technology is inadequate or where additional research is required.

To develop direction for the program, USACE established an ad hoc committee of engineers and scientists. The committee formulated the objectives of the program, developed its operation philosophy, recommended funding levels, and established criteria and procedures for project selection. A significant result of their efforts was a prioritized listing of problem areas to be addressed. This is essentially a listing of the areas of interest of the program.

USACE offices are invited to nominate projects for inclusion in the monitoring program as funds become available. The MCNP program is governed by Engineer Regulation 1110-2-8151 (HQUSACE 1997). A selection committee reviews and prioritizes the nominated projects based on criteria established in the regulation. The prioritized list is reviewed by the program monitors at HQUSACE. Final selection is based on this prioritized list, national priorities, and the availability of funding.

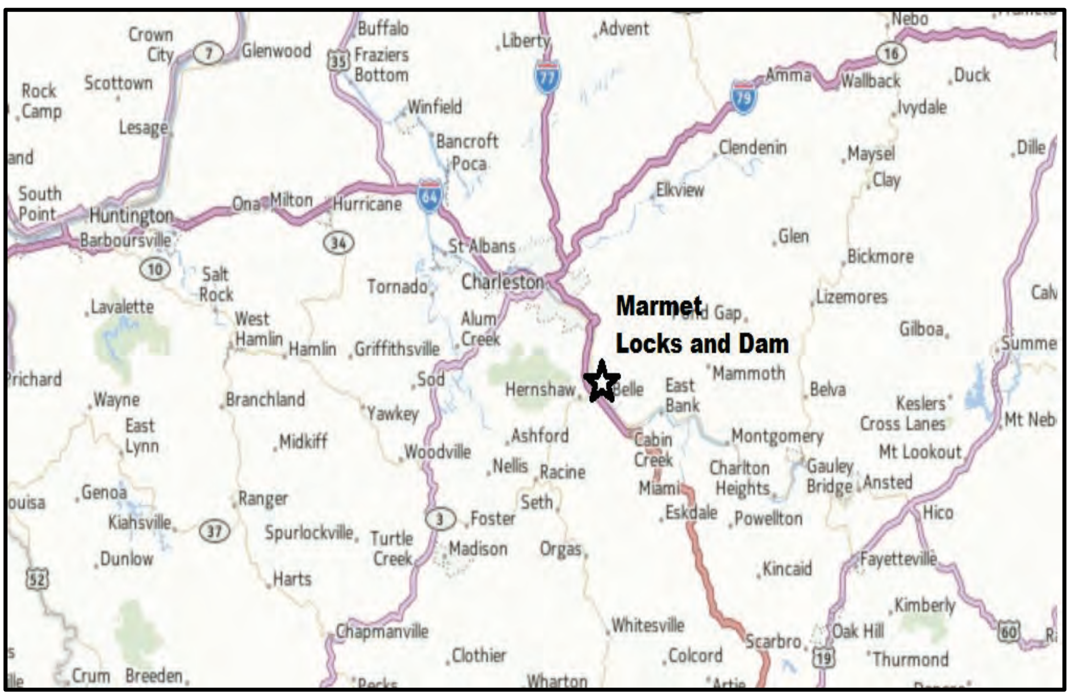
The overall monitoring program is under the management of the ERDC-CHL, with guidance from HQUSACE. An individual monitoring project is a cooperative effort between the submitting District and/or Division office and CHL. Development of monitoring plans and conduct of the study,

including data collection and analyses, are dependent upon the combined resources of CHL and the District and/or Division.

Location and description of Marmet Locks and Dam

The Marmet Locks and Dam are located approximately 68 miles above the mouth of the Kanawha River at Marmet, WV, approximately 9 miles upstream of Charleston, WV, and approximately 27 miles from the head of navigation (Figure 1). The original twin locks built in 1934 measured 56 feet (ft) wide by 360 ft long. During the 1930s, this was large enough to handle the traffic of the Kanawha River. In recent years barges have increased from the 175 ft standard barge to the massive 35 ft by 195 ft jumbo barge. These new barges can carry up to 2,000 tons, one and a half times the capacity of the standard barge of the 1930s. This larger barge, combined with the increase in traffic, created a bottleneck effect at the Marmet Locks and Dam.

Figure 1. Marmet Locks and Dam, Kanawha River, WV, vicinity map.



The USACE was authorized by Congress (Water Resource Development Act of 1996) to build a larger lock adjacent to the existing locks to accommodate the increased traffic at Marmet Locks and Dam. The project required the acquisition of 216 tracts of real estate and relocation of 252 residences and businesses. The contract for the new Marmet Lock was awarded on 28 May 2002 to Kokosing/Frucon, LLC, and construction began in the summer of

2002. The new lock became operational on 22 January 2008. It is estimated that the average transit time has been reduced from approximately 4 hours (hr) to approximately 0.8 hr. At current traffic levels, this would yield over 16,500 hr of trip time savings for the 4,210 tows that use the Marmet project. In 2010, more than 16.4 million tons of commerce locked through Marmet, including 15.4 million tons of coal, which is used mostly for power generation.

The project consists of the new 110 ft by 800 ft lock, the two original 56 ft by 360 ft locks, a non-navigable gated dam, and a 3-unit hydroelectric power plant (Figure 2). The dam is 557 ft long and consists of five roller-type gates, each of which spans 100 ft between concrete piers. The power plant is owned by Kanawha Valley Power Company and is capable of producing 144,000 kilowatts. The new lock is located on the east side of the old locks and has a design lift of 24.0 ft. This condition occurs with a normal upper pool elevation (el) of 590 ft and a normal lower pool el of 566 ft. The new lock features a through-the-sill intake, a longitudinal in-chamber filling and emptying system, and a conventional sidewall discharge manifold in the lower lock approach. In addition, when the new lock was replaced, the upper and lower guide walls were replaced.

Figure 2. Marmet Locks and Dam, Kanawha River, WV.

Purpose of the study

The general design of the project was based on model studies conducted at ERDC. Two physical models were used to evaluate and improve proposed designs. There were a 1:25 scale filling and emptying model used to evaluate proposed designs for the filling and emptying system (Hite 1999) and a 1:100 scale navigation model to investigate and evaluate proposed channel and lock wall designs for the new lock (U.S. Army Engineer Waterways Experiment Station 1996).

The purpose of this current MCNP Marmet Locks and Dam monitoring project is to evaluate the performance of the final design after construction and to determine if the design was functioning as expected based on the model results. This study provides engineers at the ERDC and the U.S. Army Engineer District, Huntington (LRH), the opportunity to evaluate the performance of the new, unique features of the project. It was nominated by LRH and selected by HQUSACE for monitoring because of the many unique and innovative aspects of the project and because multiple models had been used during the design phases. The upstream lock wall is innovative because it is a long-span, thin-walled design and, based on input from the towing industry during the modeling, has a land side *guide wall* instead of the more common riverside *guard wall*.

Monitoring plan

It was important to confirm the findings of two physical model studies of these unique features by comparing model results to prototype field data under actual operating conditions. Four important components of the new Marmet Lock and vicinity were monitored and evaluated by the MCNP Product Delivery Team (comprised of ERDC and LRH personnel), including the (a) lock filling and emptying system, (b) in-chamber culvert tunnels and Stoney gate valves, (c) upstream guide wall, and (d) upper and lower lock approaches scour potential.

Lock filling and emptying system

The system incorporates an intake under the miter gate sill. This concept was developed because of great cost savings that would result from using roller compacted concrete (RCC) in the lock walls. The more conventional construction of navigation locks requires large concrete gravity walls with the culverts inside the walls. Not only did this in-chamber filling and

emptying system save money, but it also resulted in a more compact lock design that used less real estate. (RCC drove the design of the filling and emptying system, but RCC was not actually used in the final construction.)

Because of uncertainties pertaining to the hydraulic conditions within the culvert system in the presence of high-velocity flows and 90-degree turns, a numerical model study of the lock culvert system was developed to provide velocity and pressure information throughout the system (Stockstill 2015).

In-chamber culvert tunnels and Stoney gate valves

Due to high-velocity flows in the culvert tunnels, there were corresponding concerns about concrete erosion and cavitation of the Stoney gate valves that were used instead of the common reverse tainter valves. Stoney gate valves are not a new design, but the ones used in the new Marmet Lock are unusually large (13 ft wide by 15 ft high). They are basically vertical steel lift gates installed in the culverts and are raised and lowered by electric motors. Remotely operated vehicle (ROV) surveys were conducted.

Monitoring tows at upstream guide wall with time-lapse video

Another innovative and unusual aspect is the upstream lock guide wall. Typically, modern lock designs include a riverside guard wall to assist tows entering the lock from upstream, so called because it guards the tow from being drawn to the spillway. However, due to input from the towing industry during the navigation model study, the new Marmet Lock has a 1,600 ft-long landside guide wall, referred to as such because the tow uses it to align itself with the lock chamber. The wall guides the tow into the chamber. This structure is thin-walled to reduce weight for placement during construction, and there was concern about impact loads on the wall from barges aligning with the lock chamber. Video monitoring was utilized in the analysis of barge impact on the guide wall.

Upper and lower new lock approaches scour potential

Filling underneath the upstream miter gate sill could pose a hazard to both towboats and small watercraft. One thing to consider was potential seiches or oscillations while filling the chamber. Other considerations included vortex formation outside the upper miter gate during filling and turbulence created in the lower approach while emptying the chamber. From a

maintenance point of view, the through-the-sill intake may also be prone to driftwood and trash accumulation and may require periodic cleaning.

There was concern about the possibility of high velocities during filling and/or emptying causing scour or deposition in the lock approaches. To monitor these phenomena, LRH surveyed the approaches annually. These data were then analyzed by ERDC to determine if bathymetric changes due to scour or deposition were taking place in the upper and lower lock approaches.

2 Field Data Collection and Analyses

The new Marmet Lock filling and emptying system is unique and innovative. It consists of a through-the-sill intake, Stoney gate valves, and in-chamber longitudinal culverts. There was concern regarding the collection of debris immediately upstream of the intake and on the intake trash racks themselves, as well as tow impacts on the upstream guide wall. There was also concern about the performance and durability of the Stoney gate valves and the hydraulic performance of the in-chamber culverts with regions of very high velocity and very low pressure. Knowledge of the overall hydraulic performance of the filling and emptying system as compared to the model studies was essential.

The upstream intake, Stoney gate valves, in-chamber culverts, and the discharge outlets were monitored each year (2010, 2011, 2012, and 2013) using an ROV. Video was recorded of each, and a team was assembled at the site each year to observe the live video and evaluate the performance of each. The hydraulic performance of the filling and emptying system was partially evaluated using a celestial scanner and custom-designed floats in the lock chamber. The positions of the floats were tracked during several filling scenarios and compared to data from the filling and emptying model study. These data were also used to help validate a lock simulation numerical model (LOCKSIM). That numerical model simulation study is reported by Stockstill (2015).

Lock filling and emptying system

A schematic of the Marmet Lock filling and emptying system is shown in Figure 3. The under-the-sill filling system is shown in Figure 4 during construction, also showing the trash racks to prevent driftwood and debris from entering the culvert system. The entire in-chamber culvert system is shown in Figure 5 during construction.

The intent was to place instrumentation into the prototype flow field to measure velocities and pressures to determine if there were sufficient high velocities or low pressures to cause adverse conditions to exist during various operational situations. It quickly became apparent that any instrumentation placed in the flow field would be too intrusive and produce erroneous data. Furthermore, any instrumentation placed in this high-velocity environment would be quickly swept away by the currents.

Figure 3. Marmet Lock filling and emptying system (flow from left to right).

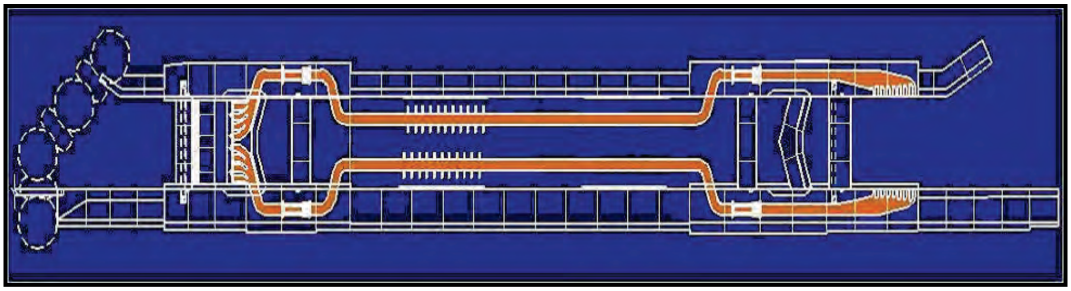


Figure 4. Marmet Lock through-the-sill filling system and trash racks.

Figure 5. Marmet Lock in-chamber longitudinal culvert system during construction.

The filling and emptying system of Marmet Lock was evaluated by Stockstill (2015) using the one-dimensional unsteady flow model (LOCKSIM) (Schohl 1999). The approach taken was to construct a numerical model of the Marmet Lock system, validate the model with field data, and then investigate hydraulic conditions with various operational schemes for both filling and emptying. Information gathered from previously published physical and numerical studies of the Marmet Lock supplemented field data to develop an understanding of the new lock's performance.

This evaluation of the Marmet Lock by Stockstill (2015) determined that the hydraulic conditions within the filling and emptying system for the normal operations are not much different than what was anticipated during design. The numerical model showed that the prototype lock filled in 8.4 minutes (min) and emptied in 8.0 min with a 24 ft lift. The lock culvert system experienced peak average velocities near 18 feet per second (ft/sec). Field experiments found that the project valves are operated in a manner that virtually eliminates overtravel of the lock chamber water surface, thus avoiding a reverse head on the lock chamber miter gates.

The design 24 ft lift with river conditions of an upper pool el 590 and a lower pool el 566, and using 3 min normal valve fill operations, reached total discharges near 6,900 cubic feet per second (cu ft/sec). Normal emptying operations maximum total discharge was near 7,100 cu ft/sec. Filling time with the design conditions of 24 ft lift was 8.4 min, and emptying time was 8.0 min. This compared well with the design objective of providing a construction-cost-saving innovative lock system that provided the efficiency needed to serve the needs of the USACE and the towing industry.

Pressures and discharges were computed throughout the entire filling and emptying system with design lift conditions and normal- and single-valve operations. No adverse pressures were determined by these computations.

In-chamber culvert tunnels and Stoney gate valves

Although guidance recommends using reverse tainter valves, geometric constraints forced the use of vertical-lift valves at Marmet Lock. The vertical-lift valves should continue to be inspected regularly due to their repetitive use and because of the USACE limited experience controlling lock culvert flow with valves such as these.

Stoney gate valves are vertical gates and are not uncommon (the old Marmet Locks have them as well), but the ones used in the new lock are large (13 ft wide by 15 ft high), and there is some concern about how they will perform over a long time period. Figure 6 shows two, spare Stoney gate valves that are stored on the right bank adjacent to the upstream guide wall. Figure 7 shows the machined seal on the bottom of the gate valve. Figure 8 shows the mechanical equipment used to raise and lower the Marmet Lock Stoney gate valve into the culvert system.

The Stoney gate valves and interior walls of the culvert system were inspected using an ROV. Figures 9 through 12 show the ROV used for these inspections being deployed.

The inspections consisted of looking at the rollers on the sides of the valves, the machined seal on the bottom of the valve, and the seal embedded in the concrete floor of the culvert. Figure 7 shows the machined seal on the bottom of one of the spare Stoney gate valves. Each year of the monitoring program, a team consisting of researchers from the ERDC, engineers from LRH, and lock personnel would deploy the ROV and inspect the valves. Figure 13 shows the light of the ROV in the valve well as the inspection is being performed.

Figure 6. Two spare vertical-lift Stoney gate valves stored at Marmet Locks and Dam.

Figure 7. Machined seal on bottom of Stoney gate valve.

Figure 8. Mechanical equipment used to raise and lower Stoney gate valve into Marmet Lock filling and emptying culvert system.

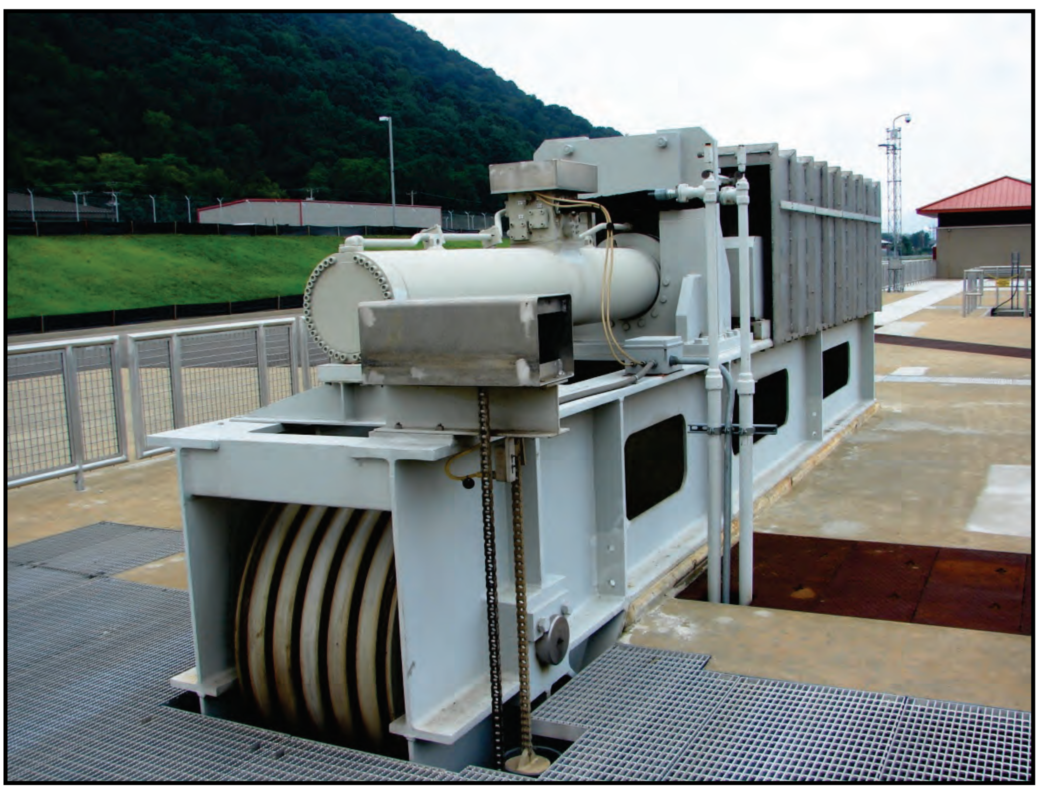


Figure 9. ROV used in Marmet Lock Stoney gate valves and culvert tunnels inspection.

Figure 10. ROV being attached to tether.

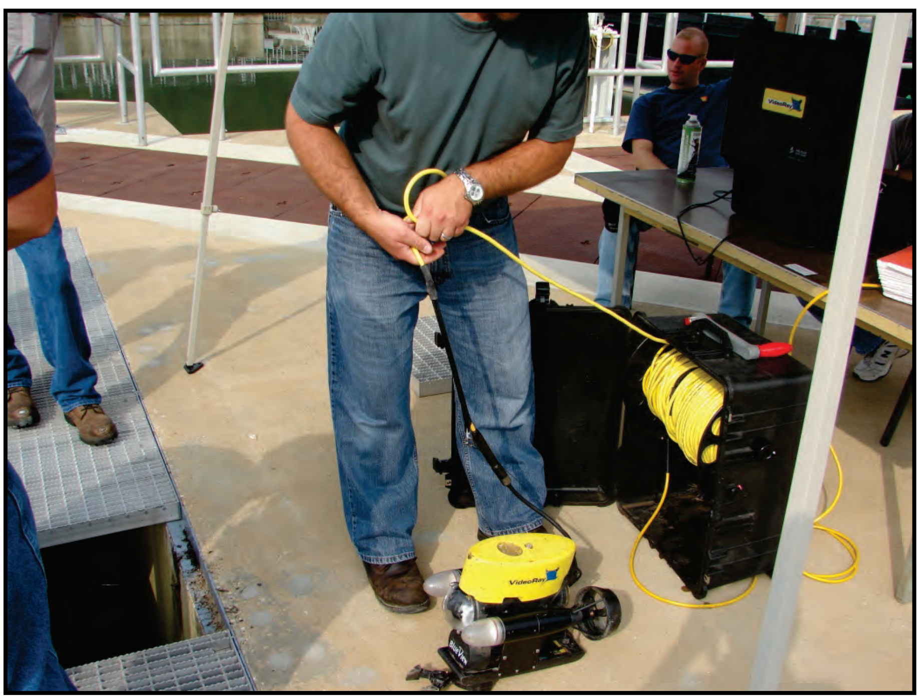


Figure 11. ROV entering valve well to Marmet Lock Stoney gate valves and culvert tunnels.

Figure 12. ROV being lowered to Marmet Lock Stoney gate valves and culvert tunnels.

Figure 13. Light from ROV performing inspection of Marmet Lock Stoney gate valve.

Figures 14 through 17 show typically representative photos of the Stoney gate valve inspection screen shots. Video of the inspections was also recorded and reviewed at a later date. After viewing the annual inspections and the videos, it was determined that the Stoney gate valves were performing well, and no cavitation or unusual wear has occurred at this time.

During the ROV inspections, the lock culverts and discharge outlets were also inspected. The ROV was maneuvered into the culverts downstream of the valves and into the discharge outlets to inspect the culvert walls. Some small pockets of erosion were discovered in the walls where small pieces of aggregate had eroded out of the concrete, but nothing substantial was noted (Figure 18). These localized areas of interest were further inspected by a dive team and confirmed to be of no concern regarding concrete deterioration. The walls of the culverts were overall in good condition.

The ROV was also used to inspect the lock filling intake. The trash racks were inspected to determine if any debris was being collected. It was noted that some debris was collecting on the trash racks (Figure 19). It was difficult to tell from the video exactly how much debris was present, but it was estimated that debris had collected on the bottom one foot of the trash racks. This should be monitored annually by a dive team, and the debris should be removed whenever it is present.

Figure 14. Representative photo of ROV inspecting Marmet Lock Stoney gate valve.

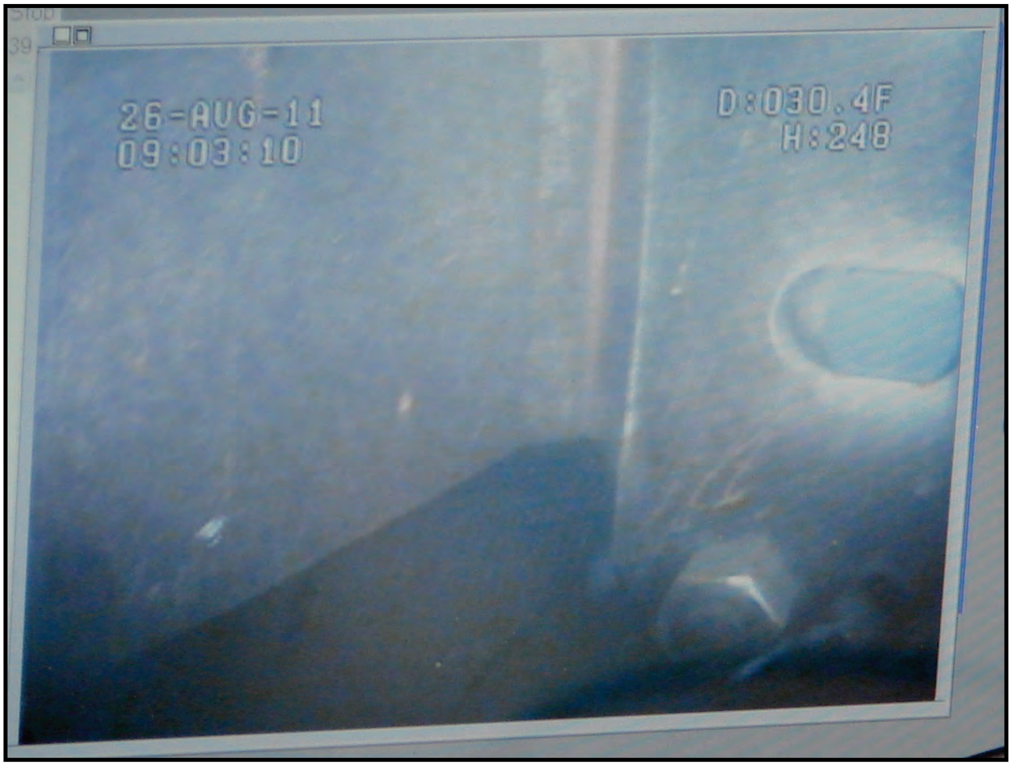


Figure 15. Representative photo of ROV inspecting Marmet Lock Stoney gate valve.

Figure 16. Representative photo of ROV inspecting Marmet Lock Stoney gate valve.

Figure 17. Representative photo of ROV inspecting Marmet Lock Stoney gate valve.

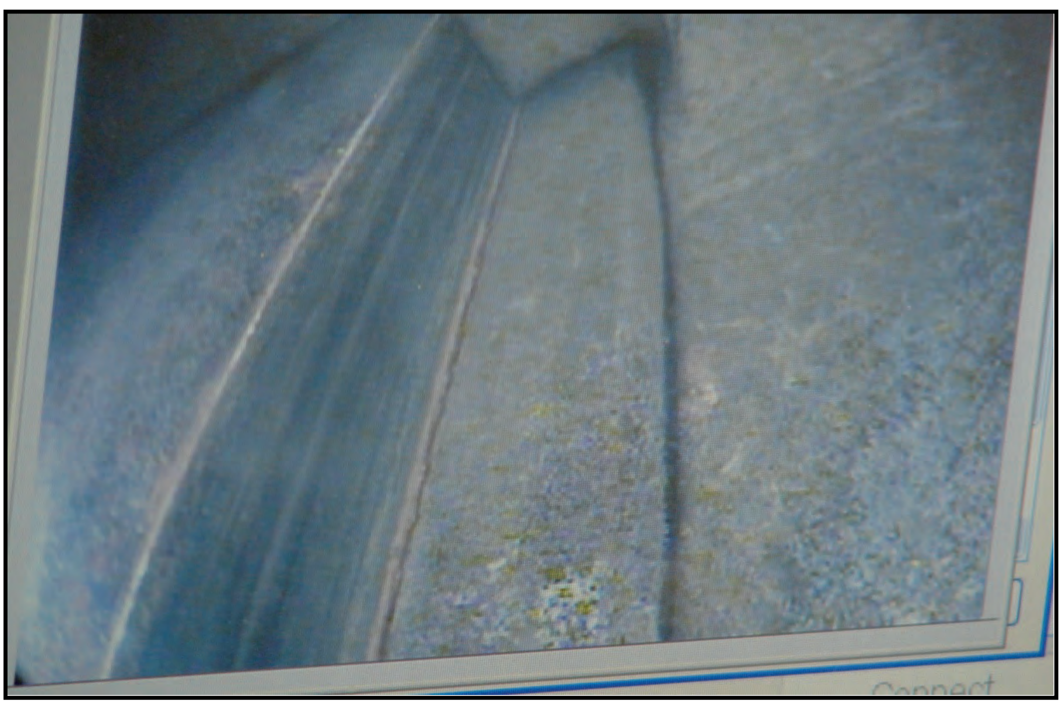
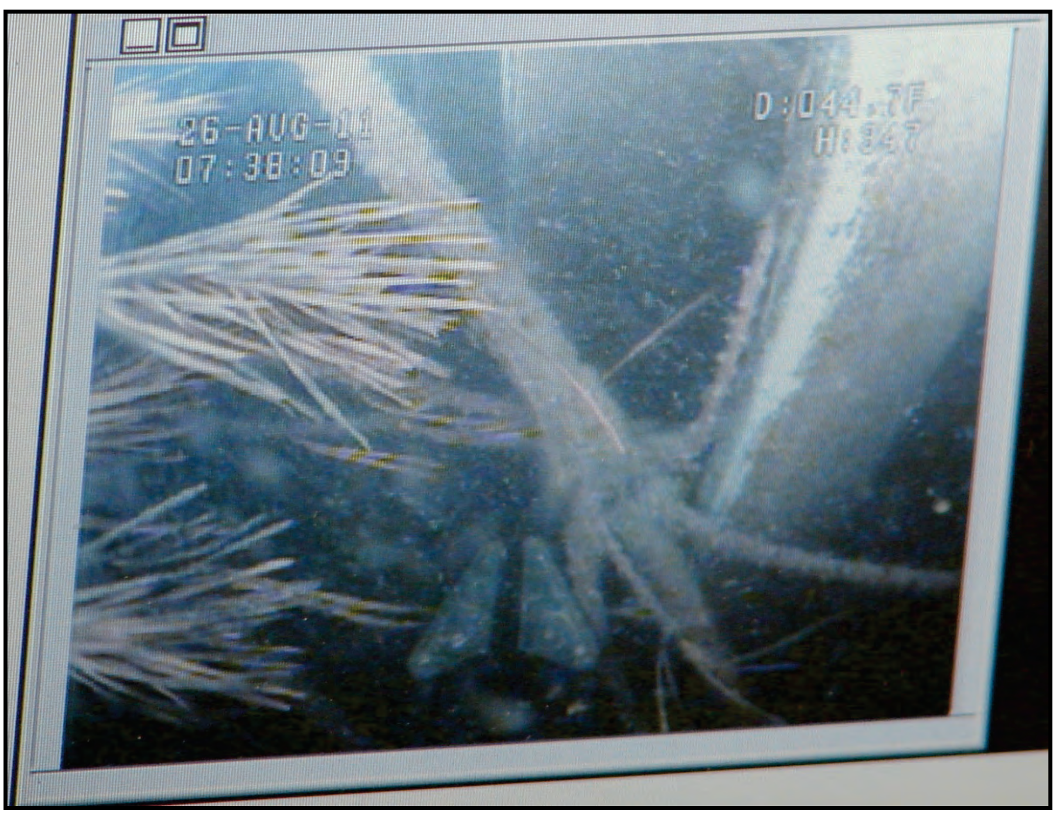


Figure 18. Minor erosion of Marmet Lock culvert concrete wall, as indicated by ROV.

Figure 19. Trash accumulation revealed by ROV inspection of Marmet Lock intake trash rack.



Monitoring tows at upstream guide wall with time-lapse video

Monitoring of the upstream guide wall was accomplished using three time-lapse video systems aimed at the upstream lock approach. Three systems were needed because of the large field of view required to capture tows using the guide wall. During the monitoring period, all vessels using the upper approach during daylight hours were videoed. The videos were recorded on VHS tapes and the tapes were mailed by lock personnel to the ERDC each week. At the ERDC, the tapes would be reviewed, and observations recorded in a spreadsheet. Data included the date, time, number of barges, load condition of the barges, whether or not a helper boat was used, location of impact (upper, middle, or lower part of wall), force of impact (high, medium, or low), and whether the bow or stern struck the wall first.

The new upstream guidewall at Marmet is innovative in design. It is a straight 1,600 ft long wall with steel wall armor for the tows to slide on. The wall consists of fourteen drilled shaft piers and a concrete-filled nose cell substructure supporting a superstructure of approximately fifteen, 500-tons-each (fifteen, 110 ft long), posttensioned concrete box beams. The fifteen, posttensioned, 10 ft by 10 ft concrete box beams were designed to withstand impact face punching shear for an extreme event impact load of 710 kips. At the same time, the structure had to be kept relatively thin walled so the beams could span 110 ft without being too heavy to lift into place with regionally available equipment. Figure 20 shows a section of the wall being placed.

Figure 20. Section of new Marmet upstream guide wall being placed.

Typically modern lock designs utilize a guard wall instead of a guide wall. A guard wall is on the riverside of the lock and protects tows entering the upstream lock approach from drifting toward the spillway. During the design process of the new Marmet Lock, a 1:100 scale navigation model was used extensively to evaluate and improve navigation into the lock. Members of the Kanawha River towing industry accustomed to navigating the existing (old) Marmet Locks and the Kanawha River were very involved in the model study, thanks to good working relationships and coordination by LRH. The representatives of the towing industry wanted a long guide wall along the riverbank side instead of a guard wall because they were accustomed to them and liked using this type of wall. The model study showed that navigation conditions in the upper lock approach at the new Marmet Lock were satisfactory with the new guide wall design, and that is what was constructed. A guard wall also exists to protect the old Marmet Locks. Figure 21 shows a cross section looking downstream across both the new Marmet Lock guide wall near the river bank and the old Marmet Locks guard wall. Figure 22 is a photo of the riverbank side of the new guide wall.

Figure 23 shows the locations and fields of view of the three time-lapse systems that were required because of the large field of view necessary to capture the barge approaches. Each system consisted of a time-lapse video recorder housed in a weather-proof enclosure (Figure 24) and a camera housed in a weather-proof enclosure mounted on an existing light pole (Figure 25). The time-lapse recorders were Samsung SRV-960As and were programmed such that a 2 hr VHS tape could record 168 hr of video. They were programmed to record video only during daylight hours. The video cameras were Nuvico CB-HDE21N-L bullet cameras.

Figure 21. Cross section looking downstream extending across both the new Marmet Lock guide wall on the right and the old Marmet Locks guard wall on the left.

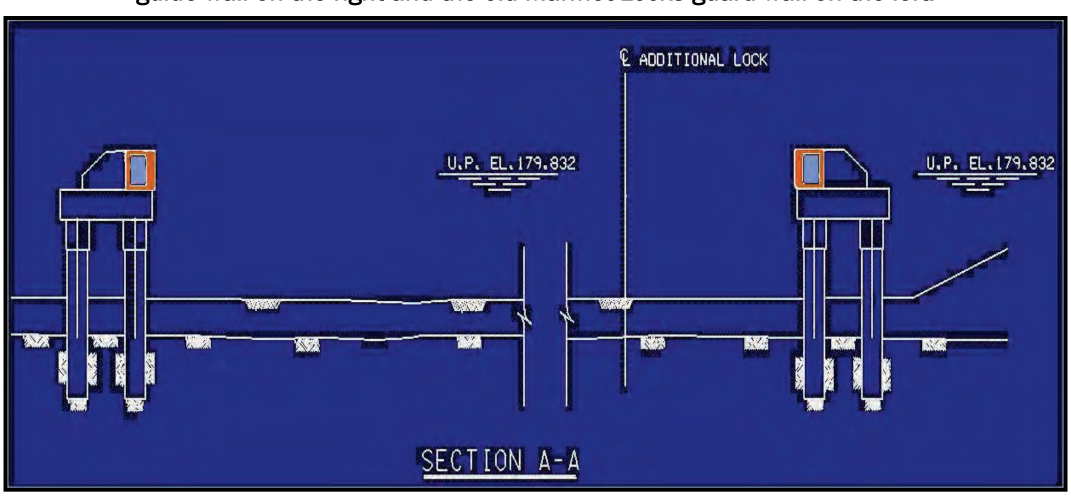


Figure 22. Riverbank side of the new Marmet Lock guide wall.

Figure 23. Locations of time-lapse video systems monitoring upper approach new guide wall.

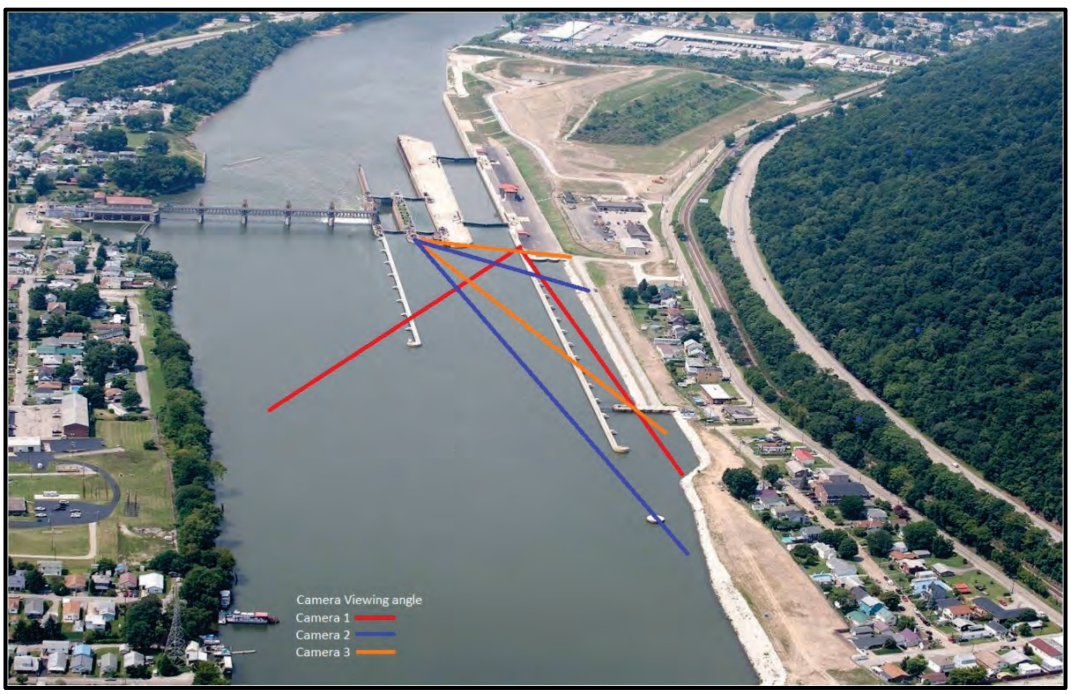


Figure 24. Time-lapse video recorders in weather-proof enclosures.

Figure 25. Time-lapse video cameras being installed on lock wall.

Table 1 lists the barge impacts for downbound lockages (data provided from the video tapes). During the monitoring period, 859 tow transits were recorded and evaluated. Of those recorded, 848 had impacts described as low impact, 7 had medium impacts, and 4 had hard impacts. Most tows entering the lock approach used the upper end of the wall and landed on the wall stern first. When entering the lock approach, the tow would normally slow almost to a stop and then ease over to the wall and allow the starboard corner of the most upstream barge to come to rest lightly on the wall.

Table 1. Barge impacts (high, medium, low) for downbound lockages utilizing the new Marmet Lock upstream guide wall, Kanawha River, WV.

Date	Time	Number of Barges	Barge Loading			Helper Boat	Impact Zone			Impact Force (H/M/L)	Orientation at Impact	
			Loaded	Partial	Empty		Upper	Middle	Lower		Bow First	Stern First
1/28/2010	9:30	6	X			X				LOW	X	
1/28/2010	11:25	6	X				X			LOW	X	
1/28/2010	16:30	6				X				LOW	X	
1/29/2010	16:45	9	X				X			LOW	X	
1/30/2010	6:42	9	X				X			LOW		X
1/30/2010	12:10	9	X				X			LOW		X
1/30/2010	13:13	9	X				X			LOW		X
1/30/2010	14:00	9	X				X			MED		X
1/30/2010	18:30	8	X				X			LOW		X
1/30/2010	20:20	6			X		X			LOW		X
1/31/2010	14:00	7	X				X			HIGH		X
9/1/2010	6:45	7	X				X			LOW		X
9/1/2010	7:50	6	X				X			LOW		X
9/1/2010	12:55	3	X				X			LOW		X
9/1/2010	17:10	9	X				X			LOW		X
9/1/2010	18:50	9	X				X			LOW		X
9/2/2010	11:50	6	X				X			LOW		X
9/2/2010	17:05	9	X				X			LOW		X
9/3/2010	10:53	9	X				X			LOW		X
9/4/2010	5:56	5	X				X			LOW		X
9/4/2010	8:10	3	X				X			LOW		X

A probabilistic barge impact analysis of the upper guide and guard walls at Marmet Locks and Dam had previously been conducted by Patev (2000). That analysis was performed for the midspan section of the guide wall. It was determined that the return period for the design load of 710 kips would be 500 yr. This present MCNP study did not measure impact loads on the guide wall.

Upper and lower new lock approaches scour potential

The upper and lower lock approaches were evaluated for potential hazardous current conditions during filling and emptying and for scour and/or deposition in these approach regions. Since the filling intake is located through the sill, flow is rapidly pulled to the intake from the upper lock approach, creating vortex-type conditions outside the upstream miter gates. Turbulent conditions during emptying might also adversely impact barge traffic. To monitor potential scour or deposition in the upper and

lower approaches, hydrographic surveys were conducted each year and compared to previous years.

The upper approach was surveyed in the summers of 2010, 2011, 2012, and 2013. The lower approach was surveyed in the summers of 2011, 2012, and 2013. During these surveys, visual observations were made of the water surfaces immediately outside the miter gates during both filling and emptying. It appeared the vortex formation outside the upstream miter gate was minimal and not a hazard to navigation (Figure 26). Similarly, the turbulence created outside the lower miter gate during emptying (Figure 27) appeared to be normal when compared to other locks with similar lock emptying discharge ports. The discharge ports at the new Marmet Lock were a conventional design used at other locks.

The bathymetric surveys collected for the upper approach are shown in Figures 28 through 31, and the surveys collected of the lower approach are shown in Figures 32 through 34. After all surveys were collected, difference maps were created for each approach between the first and last surveys. A difference map of the 2010 and 2013 surveys of the upper approach are shown in Figure 35, and a difference map of the 2011 and 2013 surveys of the lower approach are shown in Figure 36. An analysis of the surveys and the difference maps indicates that no significant scour or deposition is occurring in the approaches.

The indication of small scour upstream of the lower miter gate (Figure 33) is an artifact of the survey signals rebounding from the lock sidewalls and is not real as the bottom of the lock chamber is bed rock and will not scour. The scour in the upper lock approach (Figure 35) is of such small aerial extent as to be irrelevant and did not appear to be enlarging during the time period of these field surveys. Hence, no danger presently exists for undermining of any navigation lock infrastructure feature.

Figure 26. Minimal vortex formation outside the upper miter gate during filling.

Figure 27. Typical turbulent conditions at downstream end of lock during lock emptying.

Figure 28. Hydrographic survey of upper lock approach, 4 May 2010.

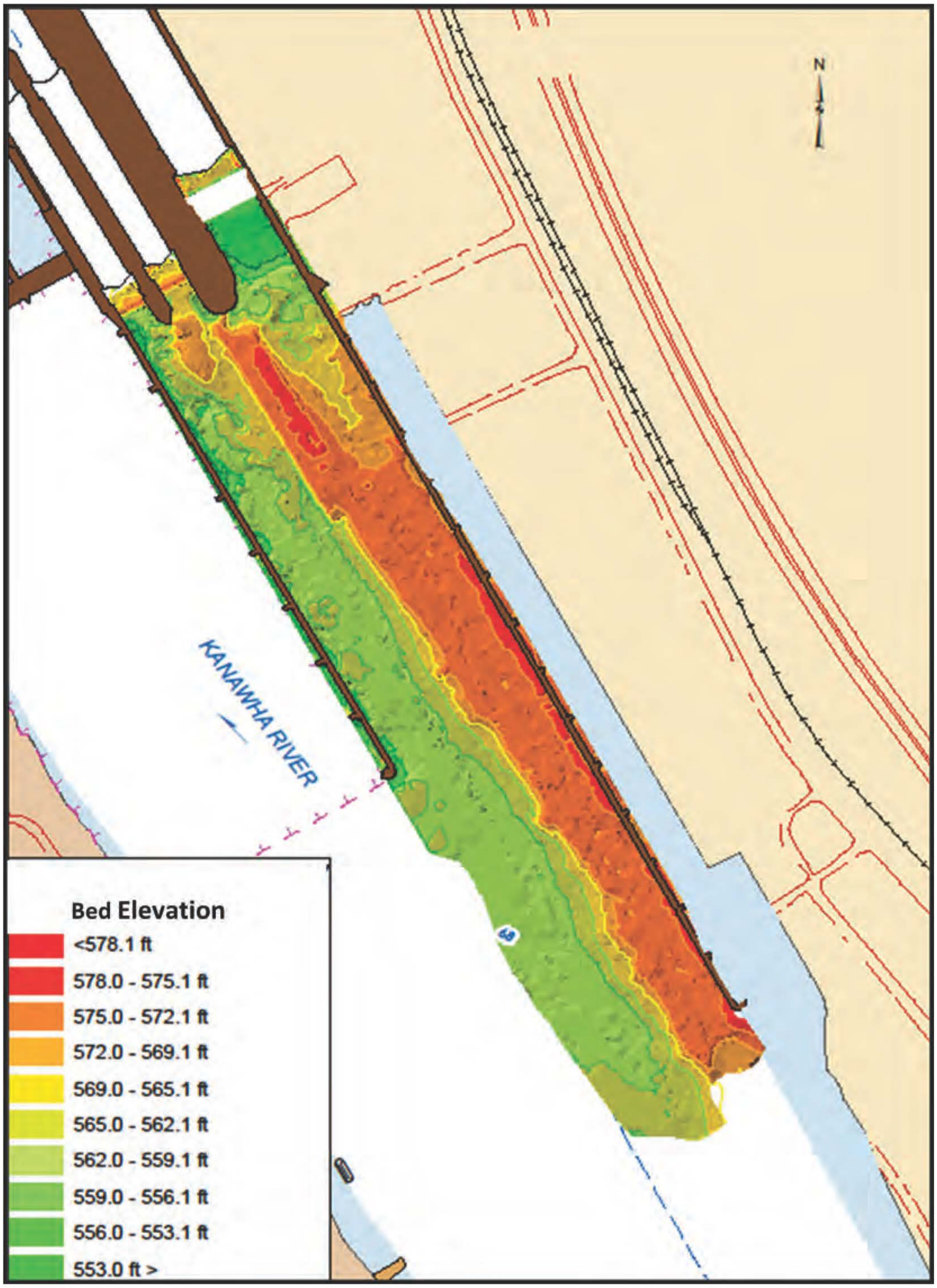


Figure 29. Hydrographic survey of upper lock approach, 5 July 2011.

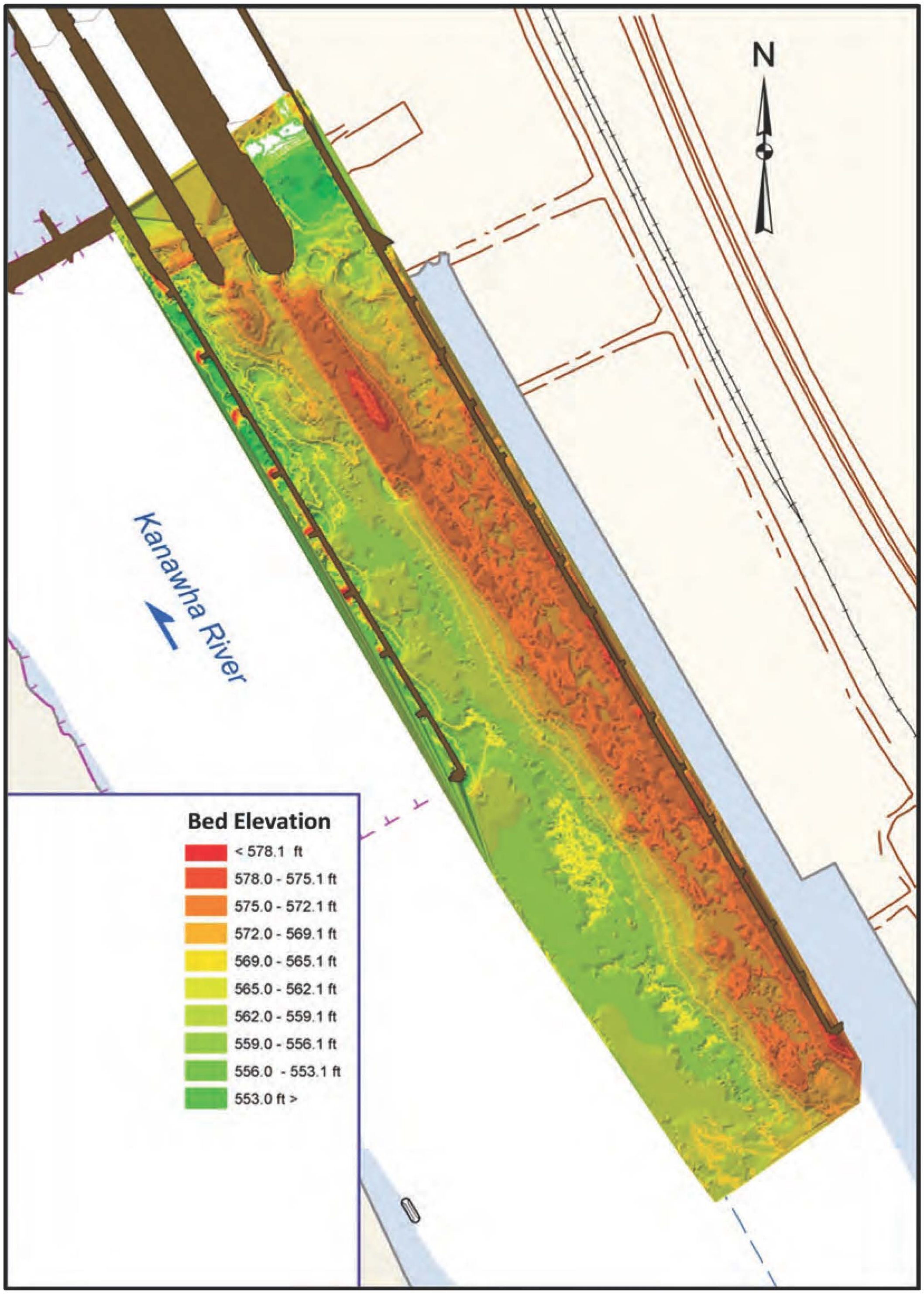


Figure 30. Hydrographic survey of upper lock approach, 21 June 2012.

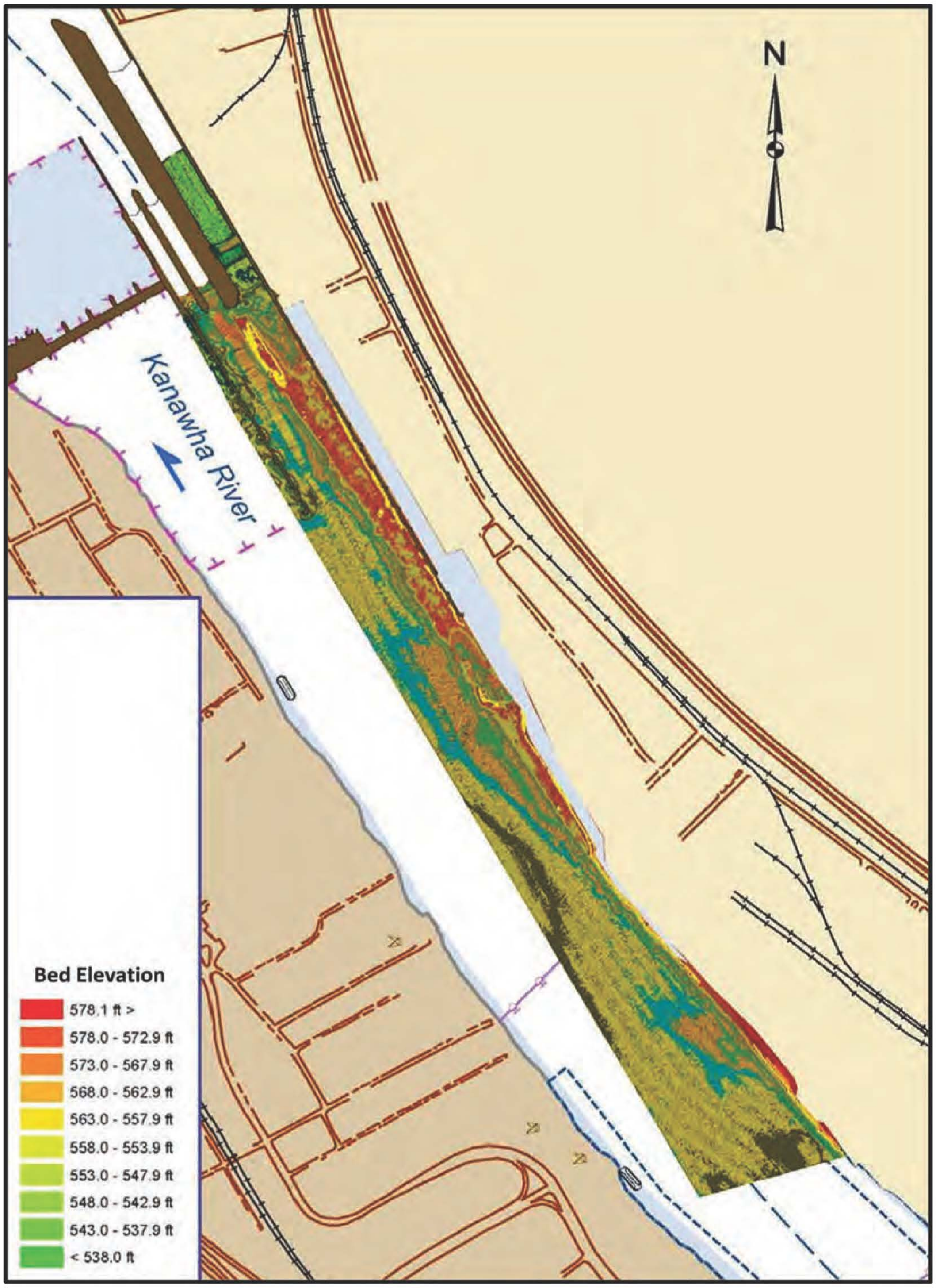


Figure 31. Hydrographic survey of upper lock approach, 5 September 13.

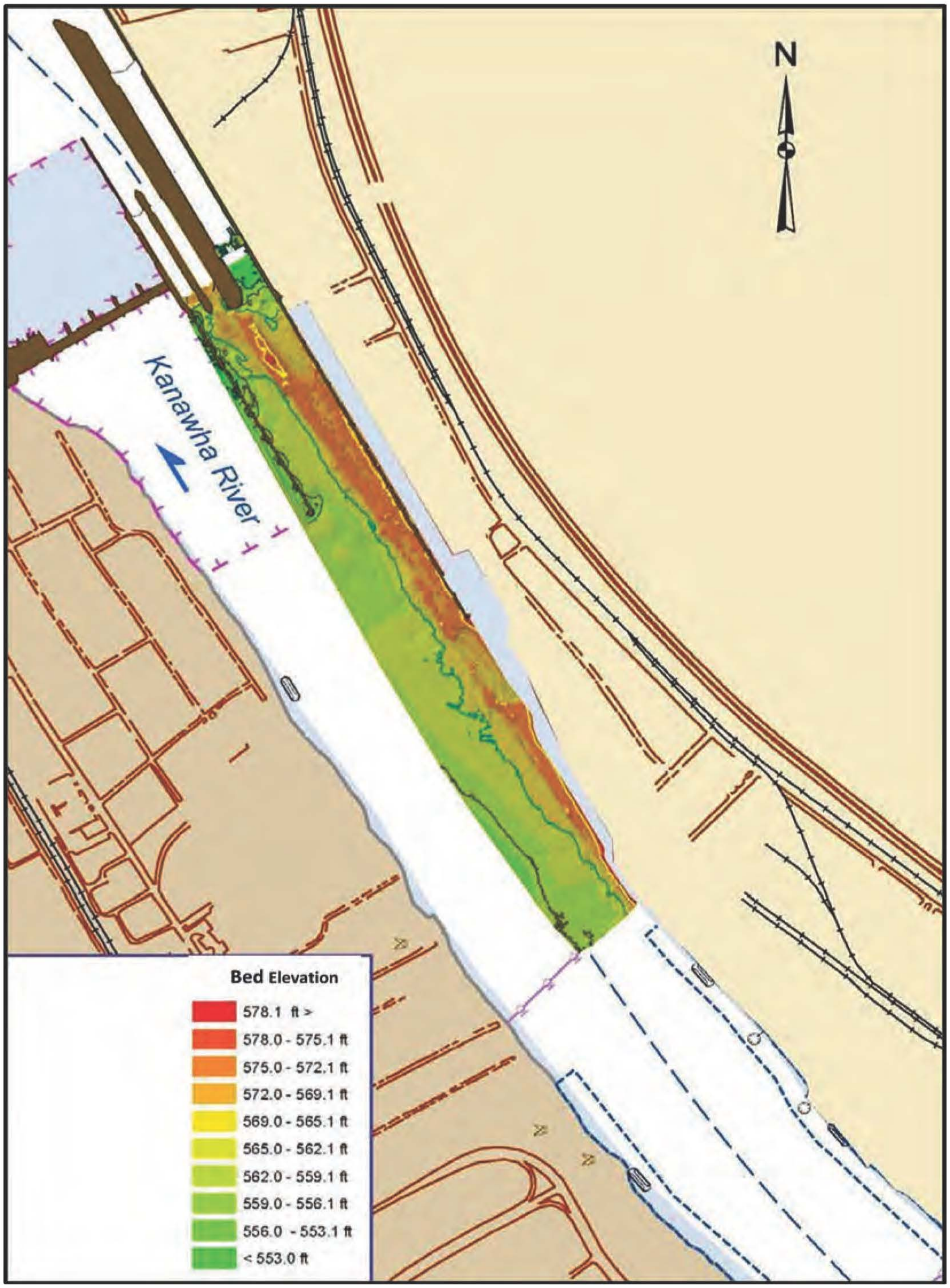


Figure 32. Hydrographic survey of lower lock approach, 5 July 2011.

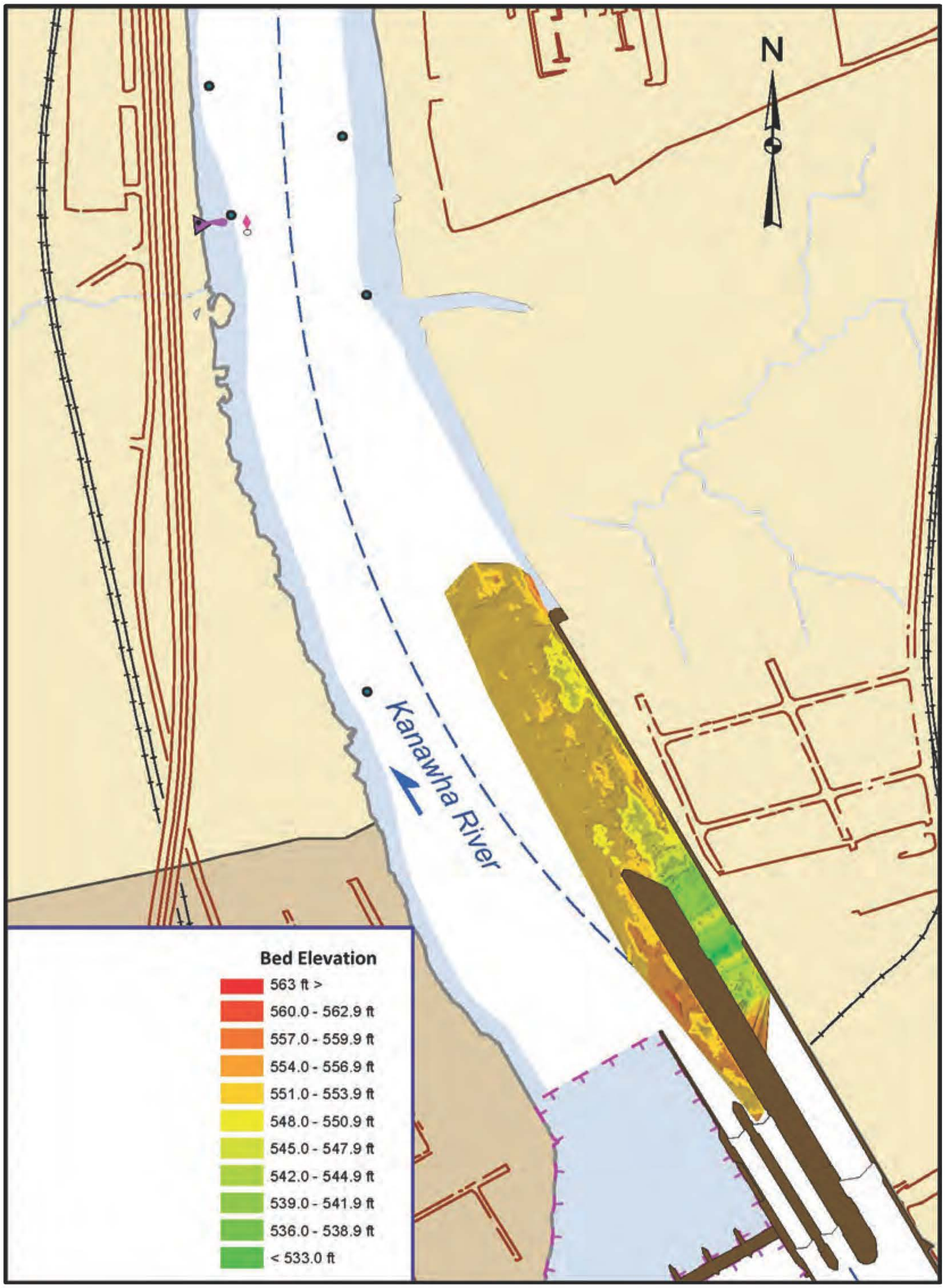


Figure 33. Hydrographic survey of lower lock approach, 21 June 2012.

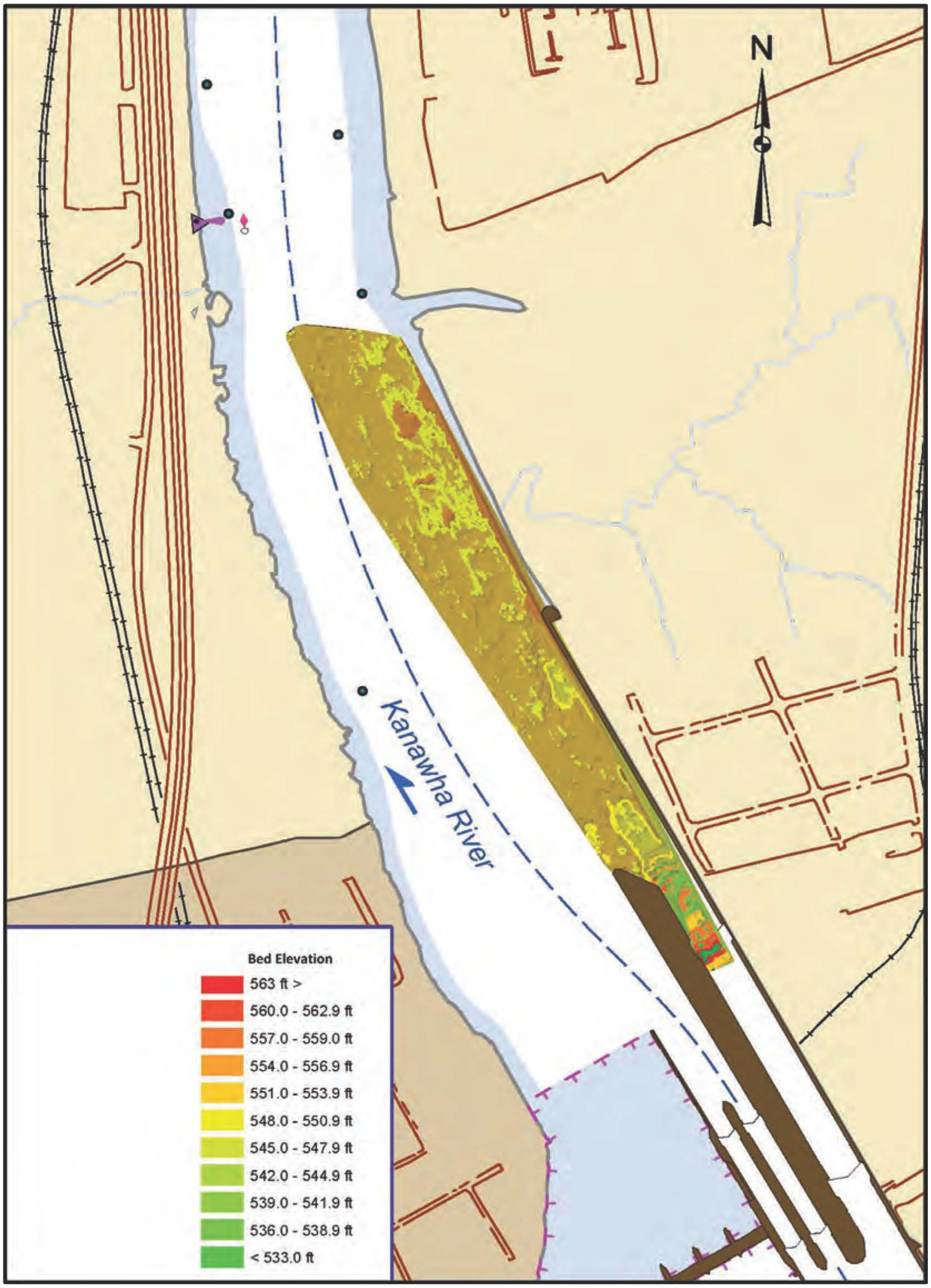


Figure 34. Hydrographic survey of lower lock approach, 31 October 2013.

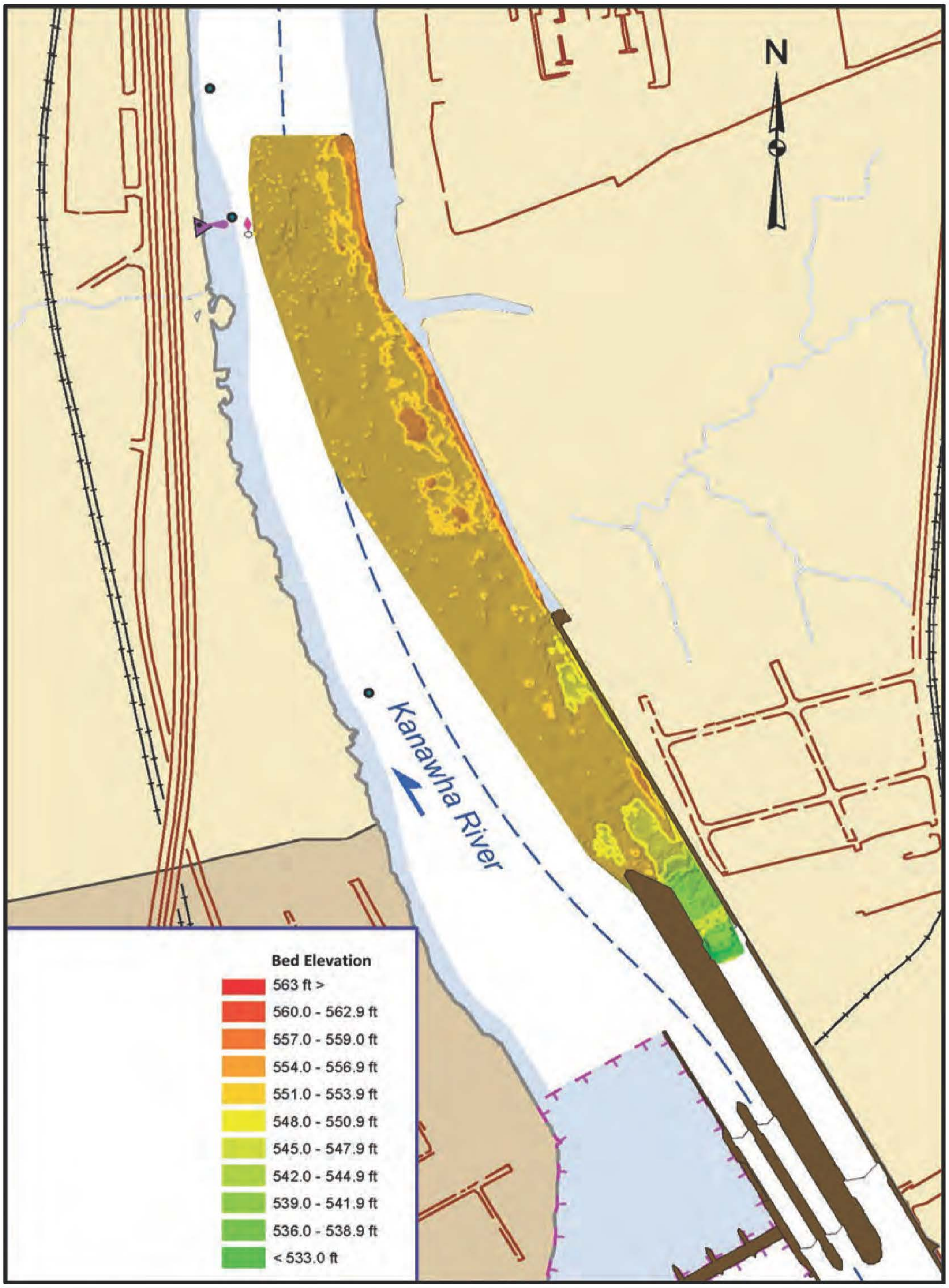


Figure 35. Difference map of 2010 vs. 2013 upper lock approach surveys.

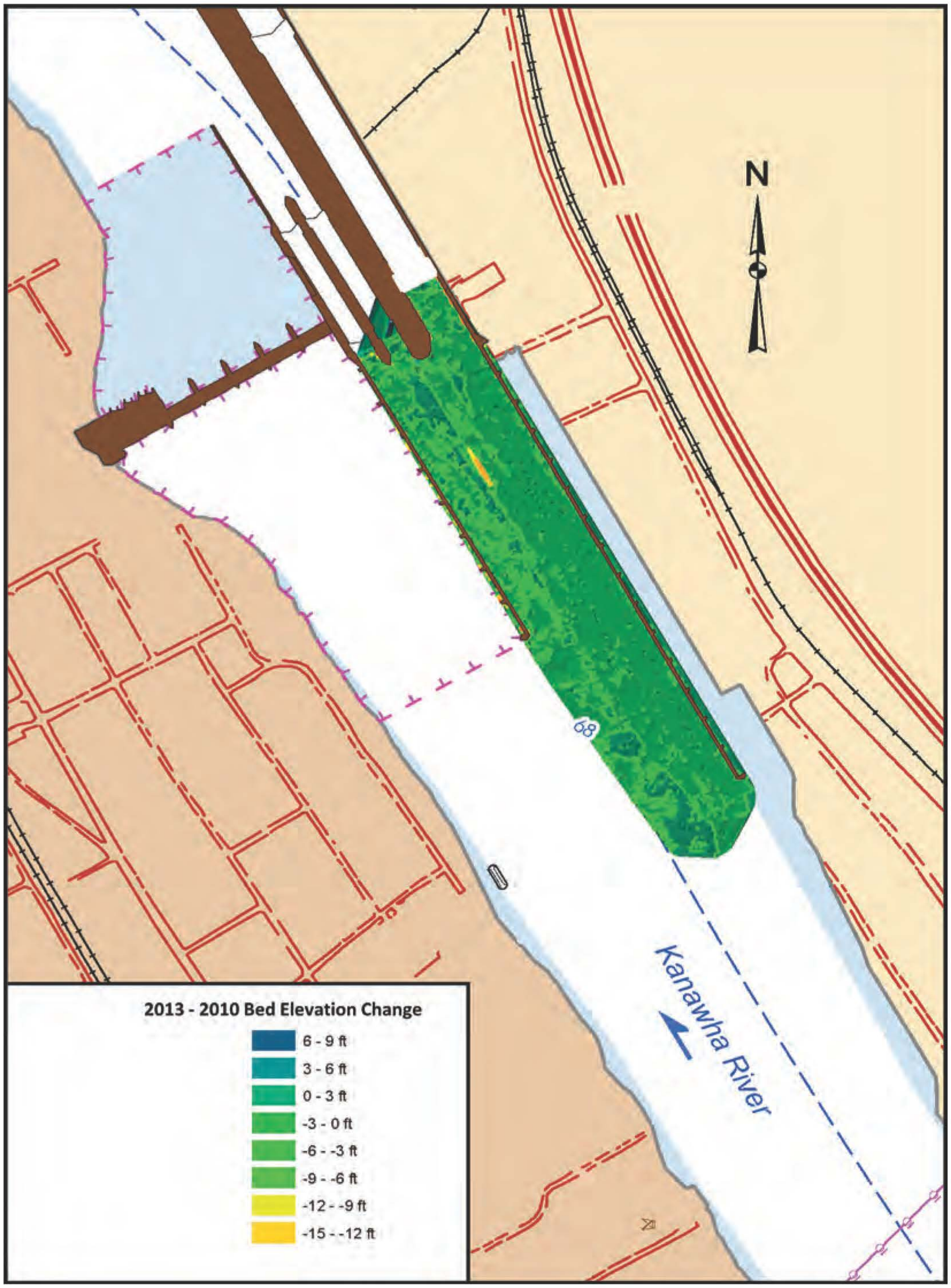
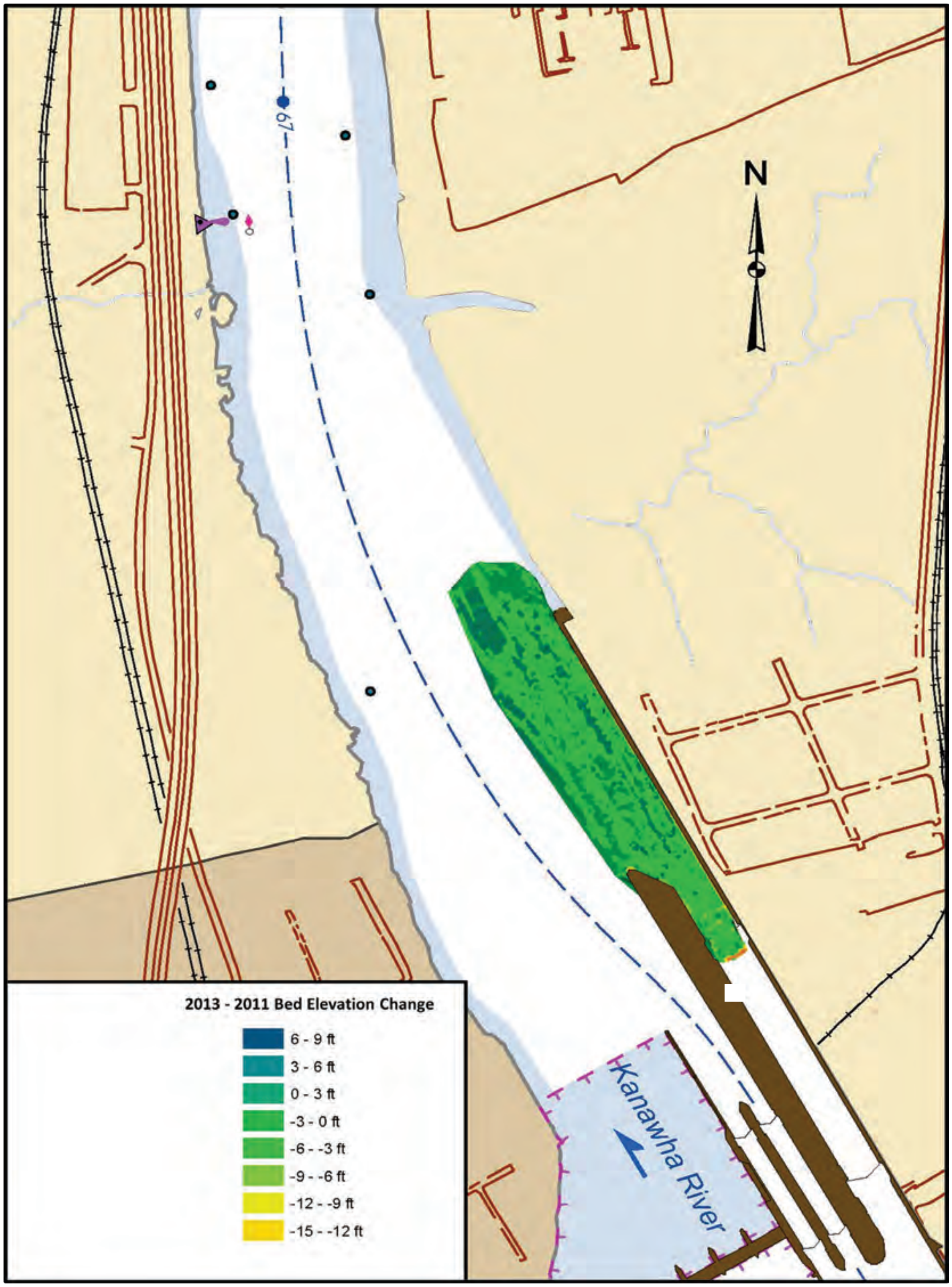


Figure 36. Difference map of 2011 vs. 2013 lower lock approach surveys.



3 Summary and Conclusions

The purpose of this monitoring study was to determine if the new Marmet Lock project is functioning as designed and as predicted by two physical model studies that were conducted at the ERDC.

Summary

Lock filling and emptying system

As extracted from Stockstill (2015), hydraulic conditions within the filling and emptying system for normal operations are not much different than what was anticipated during design. The numerical model LOCKSIM showed the prototype lock filled in 8.4 min and emptied in 8.0 min with a 24 ft lift. The lock culvert system experienced peak average velocities near 18 ft/sec. Field experiments found that the project valves are operated in a manner that virtually eliminates overtravel of the lock chamber water surface, thus avoiding a reverse head on the lock chamber miter gates.

The design 24 ft lift with river conditions of an upper pool el 590 and a lower pool el 566 found that 3 min, normal-valve fill operations reached total discharges near 6,900 cu ft/sec. Normal emptying operations maximum total discharge was near 7,100 cu ft/sec. Pressures and discharges were computed throughout the entire filling and emptying system with design lift conditions and normal- and single-valve operations. No adverse pressures were computed during for these conditions.

Although guidance recommends using reverse tainter valves, geometric constraints forced the use of vertical-lift Stoney gate valves at the new Marmet Lock. The vertical-lift valves should continue to be inspected regularly due to their repetitive use and because of the USACE limited experience controlling lock culvert flow with valves such as these.

In-chamber culvert tunnels and Stoney gate valves

An ROV was maneuvered into the culverts downstream of the valves and into the discharge outlet to inspect the culvert walls. Some small pockets of erosion were discovered in the walls where small pieces of aggregate had eroded out of the concrete, but nothing substantial was noted. These localized areas of interest were further inspected by a dive team and

confirmed to be of no concern regarding concrete deterioration. The walls of the culverts were overall in good condition.

The Stoney gate valves are performing well and are not showing any signs of unusual wear.

Monitoring tows at upstream guide wall with time-lapse video

During the monitoring period, 859 tow transits were recorded and evaluated. Of those recorded, 848 had impacts described as low impact, 7 had medium impacts, and 4 had hard impacts. Most tows entering the lock approach used the upper end of the wall and landed on the wall stern first. When entering the lock approach, the tow would normally slow almost to a stop and then ease over to the wall and allow the starboard corner of the most upstream barge to come to rest lightly on the wall. The probability of a punching shear failure is low. The design force of 710 kips has approximately a 500 yr return period (Patev 2000).

Upper and lower new lock approaches scour potential

Vortex formation outside the upstream miter gate during filling was minimal and not a hazard to navigation. Similarly, the turbulence created outside the lower miter gate during emptying appeared to be normal when compared to other locks with similar lock-emptying discharge ports.

Some minor accumulation of debris was detected on the lock-filling intake trash racks. The trash racks should be inspected annually and any debris found should be removed so the efficiency of the filling system is not adversely diminished.

No significant scour or deposition was found during the annual surveys (2010, 2011, 2012, and 2013) of the upper and lower lock approaches.

Conclusions

The lock culvert system experienced peak average velocities of 18 ft/sec, although no adverse pressures were found. ROV inspection indicated the walls of the culverts were in good condition. The Stoney gate valves are performing well and not showing any signs of unusual wear. The upstream guide wall is not being unduly stressed by tows aligning for entrance into the lock. No significant scour or deposition was found during the annual

survey between 2010 and 2013. Vortex and turbulence created during filling and emptying was not adverse. Upstream trash racks beneath the miter gates should be inspected annually.

Monitoring of the new Marmet Lock determined that the project is functioning as designed and as predicted by the filling and emptying and navigation model studies previously conducted at the ERDC during the development phase of the new lock. Overall, the new Marmet Lock is performing satisfactorily as designed.

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Monitoring of the new Marmet Lock, Kanawha River, WV, was performed from 2010 through 2013. The monitoring was conducted because of the many unique aspects of the new lock. The new lock project included a 1,600-feet-long, long-span, thin-walled guide wall in the upper approach and a unique filling and emptying system. The filling and emptying system has a through-the-sill intake, an in-chamber longitudinal culvert system, and Stoney gate valves. The lock was monitored using time-lapse video systems and an underwater remotely operated vehicle. The purpose of this monitoring study was to determine if the project is functioning as designed and as indicated by two physical model studies that were conducted at the U.S. Army Engineer Research and Development Center. The lock culvert system experienced peak average velocities of 18 feet per second, although no adverse pressures were found. A remotely operated vehicle inspection indicated the walls of the culverts were in good condition. The Stoney gate valves are performing well and not showing any signs of unusual wear. The upstream guide wall is not being unduly stressed by tows aligning for entrance into the lock. No significant scour or deposition was found during the annual survey between 2010 and 2013. Vortex and turbulence created during filling and emptying was not adverse. Upstream trash racks beneath the miter gates should be inspected annually. Overall, the new Marmet Lock is performing satisfactorily as designed.

15. SUBJECT TERMS

In-chamber culvert tunnels
Time-lapse video
Navigation lock and dam
Unique filling and emptying system
Stoney gate valves
Upstream thin-walled guide wall
Through-the-sill intake

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